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Precipitation and Streamwater Chemistry in an Undisturbed Watershed in Southeast Alaska

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Abstract

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Water chemistry samples have been taken from streamflow since 1976 and precipitation since 1978 in Indian River, an undisturbed watershed on Chichagof Island in Southeast Alaska. Volume-weighted concentrations of total nitrogen, ammonium nitrogen, nitrate nitrogen, total phosphorus, orthophosphate, sulfate sulfur, chloride, bicarbonate, silica, calcium, magnesium, sodium, and potassium were used with precipitation and streamflow volumes to calculate annual input and output of elements. Total nitrogen accumulated at 1.0 kg/ha per year and ammonium-nitrogen at 3.3 kg/ha per year; other monitored elements showed a net loss or export from 0.1 kg/ha per year of total phosphorus to 256 kg/ha per year of calcium. Precipitation and weathering of soil and bedrock material account for these elemental losses in streamflow. The geochemistry of Indian River is compared to other studies done in mountainous forested watersheds.

Keywords: Water analysis, nutrient budget, precipitation, streamflow, southeast Alaska.

Introduction

Precipitation and streamflow measurements have been collected in Indian River since 1976 (fig. 1). Water chemistry samples have been collected from streamflow waters since 1976 and precipitation chemistry measured since 1978. The objective is to characterize the hydrology and elemental balances in the study area. The valley forests are being logged for the first time, and logging and associated impacts on water quantity and quality will be measured in later efforts.

Pretreatment results from a case-history study of precipitation and streamwater chemistry are presented. From these, a basis for evaluating timber harvest impacts in this watershed can be developed.

Nutrient budgets have not been developed for Southeast Alaska watersheds and we have little understanding of the biogeochemical processes that control streamflow chemistry. This investigation of bulk inputs and outputs did not attempt to differentiate elemental exports from pedogenic or bedrock weathering.

To understand the biogeochemical behavior of terrestrial ecosystems, a budgetary approach, which assesses inputs to and outputs from small watershed ecosystems, is often used. Investigations into the control of inputs and outputs of elements have been made through intensive measurements of single watersheds. Paired watersheds are often used to measure land-management impacts. Departures in water chemistry in the treatment watershed are attributed to the management activity. This approach has produced hypotheses for the understanding of specific situations.

Water-balance measurements of precipitation and streamflow were used in conjunction with volume-weighted concentrations. Climate may affect water quality by determining the absolute amount of water input as a diluting influence, as well as regulating losses to evapotranspiration as a concentrating effect. Streamflow volume for the Indian River basin is 81 percent of the precipitation volume.

Cation outputs in streamwater from a forested watershed in the Oregon Cascade Range were related to the amounts in excess of the annual requirements of the forest vegetation (Fredriksen 1972). The cation source was chemical weathering of the forest soil. Other studies, however, have indicated bedrock weathering rather than soil weathering was primarily responsible for chemical composition of streamwater. Active chemical weathering was found in the absence of biological and pedogenic processes (Reynolds and Johnson 1972).

The generation of mobile anions and concomitant cation leaching will also define the weathering rate and solute removal in some soils. Cations may be leached when the cation equivalence is greater than the available capacity for cation exchange in the soil.

Outputs are considered to originate from precipitation and pedogenic and bedrock weathering. Definition of these components will occur as nutrient budgets are better defined for ecosystems in Southeast Alaska.

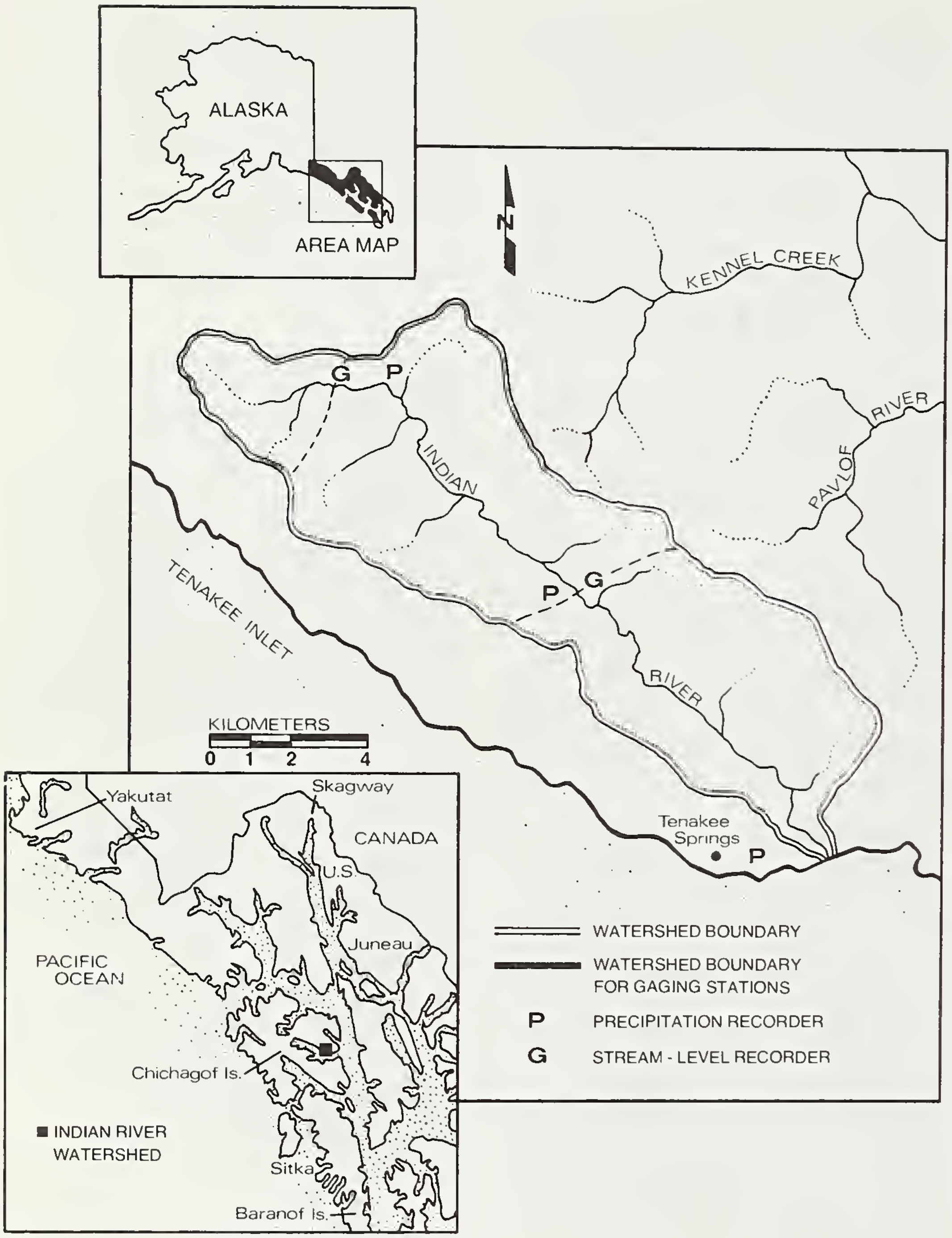

Figure 1.—Key and vicinity maps for Indian River.

Methodology

Site Description

Indian River Valley is a broad U-shaped valley near Tenakee Springs on Chichagof Island in Southeast Alaska (fig. 1). The valley is approximately 50-percent forested with a mature coastal Sitka spruce (*Picea sitchenis* (Bong.) Carr.) -western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) forest. The nonforested alpine areas are generally above 770 m with mountain peaks up to 960 m. The watershed area is 72 km^2.

Geology

Freshwater Bay is northeast of Indian River and is the northeast fold of a syncline in sedimentary and volcanic rocks that range in age from Silurian to Mississippian (Loney et al. 1975). These are gently folded and are metamorphosed in the vicinity of granitic rock masses. The head of Indian River is a syncline in this material. The valley bottom is composed of unconsolidated alluvium, colluvium, and glacial sediments. Subsurface water may flow through these sediments and not be measured as streamflow. Deep percolation of groundwater is prevented, however, by a marine till that underlies the valley bottom. The valley follows the northwest-southeast strike of the Indian River Fault, with a linear outcrop of Kennel Creek limestone on the east side. Upper elevation rocks are intrusive igneous composed of hornblende, adamellite, biotite alaskite, and biotite-hornblende meladiorite. The western valley wall (of lower elevation) is composed of intensely folded, interlayered hornfels, schist, and amphibolite (Loney et al. 1975).

Soil

Alpine areas are characteristically steep with shallow soils and frequent bedrock outcrops and talus slopes including alpine and subalpine meadows, brush slopes, and muskegs. The alpine soils are largely organic, poorly drained, and acidic. Soils on the brushy slopes are mineral and acidic but well drained. These soils have characteristically thick, rapidly decomposing layers of surface litter over 15-30 cm of dark and friable, gravelly silt loam. The alpine and brush soils may occupy slopes greater than 100 percent.

Muskeg soils (Histosols) have a water table at or close to the surface year-round and may support Alaska-cedar (*Chamaecyparis nootkatensis* (D.Don) Spach) and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) in areas where the water table is below the surface. The forested mineral soils lower in the valley are composed of alluvial and colluvial materials. These soils have thick surface organic horizons and are typically well drained.

Vegetation

The valley forest is primarily western hemlock and Sitka spruce with occasional clusters of Alaska-cedar. A variety of lodgepole pine is found on poorly drained sites. Dwarf mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) is often associated with muskegs and alpine areas. Alder (*Alnus rubra* Bong. and *A. sinuata* (Regel) Rydb.) line some streams and dominate landslides or other exposed mineral soil areas. The lodgepole and alder species are noncommercial.

The understory vegetation is characteristically blueberry (*Vaccinium ovalifolium* Sm.), huckleberry (*V. parvifolium* Sm.), rusty menziesia (*Menziesia ferruginea* Sm.), and devilsclub (*Oplopanax horridus* (Sm.) Miq.). Muskeg areas are dominated by sphagnum mosses, sedges, rushes, and ericaceous shrubs. Alpine areas are largely composed of heaths, grasses, and deer cabbage (*Fauria crista-galli* (Menzies) Makino).

Streamflow

Indian River annual streamflow ranges from 1800 to 2400 mm and averages 2200 mm distributed in a bimodal pattern (fig. 2). Tenakee Springs (at sea level) has a long-term annual precipitation average of 1700 mm; short-term measurements in the valley indicate about 2700 mm. Precipitation and streamflow measurements in the valley indicate orographic effects and storm-front funneling. Precipitation events may produce small cyclonic cells that result in localized precipitation. About 40 percent of the annual precipitation occurs as rainfall in September and October. Most precipitation occurs as snow in March or April. Fall peakflows are reduced as snow accumulates. Winter low flows occur until May or June when rain, snow melt, or both often create peakflows. Decreasing rainfall through summer results in a generally receding hydrograph. Fogs and mists contribute an additional but undetermined quantity of water.

A continuous stream-level recorder was installed at midvalley in 1976 at an elevation of 100 m and drainage area of 34.2 km^2. The gaging cross section was located in a gravelly bottomed stream reach and was resurveyed for the stage-discharge calibration annually. Streamflow measurements over the 4-year period for weekly flows were accurate to $\pm$ 10 percent. The results reported here are from this midvalley gaging station.

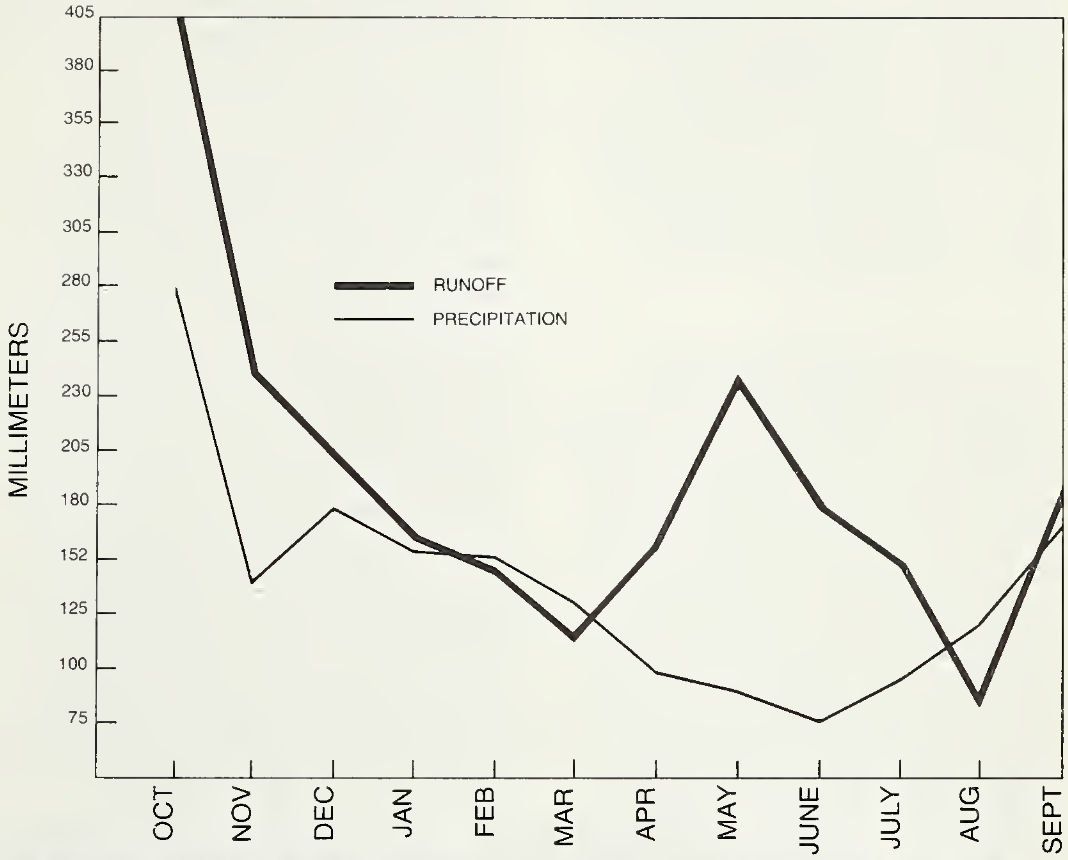

Figure 2.—Average monthly Indian River streamflow at gaging station (4 yr) and Tenakee Springs precipitation (10-yr average).

Water Sampling and Analysis

Surface grab-samples of Indian River water were collected during instrumentation servicing trips, about every 2 weeks during the summer and every 3-4 weeks in winter, depending on access. Precipitation samples were taken as an aliquot of precipitation collected in weighing recorders near the stream-level recorder and at the valley mouth. Spun fiberglass kept detritus and other debris out of the collected precipitation water. Snow samples were taken by collecting surface snow in wide-mouth sampling bottles.

Results

All samples were frozen, unfiltered and unpreserved, and shipped to the USDA Forest Service Forestry Sciences Laboratory in Corvallis, Oregon, for analysis. Samples were analyzed for total nitrogen, ammonium nitrogen, nitrate nitrogen, total phosphorus, orthophosphate, sulfate sulfur, chloride, bicarbonate, silica, calcium, magnesium, sodium, and potassium.

A pH meter with an automatic titrator measured alkalinity as bicarbonate (HCO_3–C) and pH (American Public Health Association 1975). A Varian 1200 Atomic Absorption Emission Spectrophotometer was used to measure dissolved cations of calcium, magnesium, sodium, and potassium. A Technicon II Autoanalyzer was used to measure nitrogen and phosphorus forms. A copper-cadmium reductor column reduced nitrate to nitrite for measurement (Wood et al. 1967). Total nitrogen and total phosphorus were analyzed after macro-Kjeldahl and perchloric acid digestions (American Public Health Association 1975) and measured by the Berthelot reaction and molybdenum blue method, respectively (Technicon Industrial Systems 1971, Murphy and Riley 1962, Gales et al. 1966). Sulfate-sulfur was measured by the methylthymol blue technique (Gales et al. 1968). The molybdate-stannous chloride procedure was used to measure silica (Golterman 1969). Chloride was measured by using the ferricyanide method (O'Brien 1962).

Inputs and outputs were calculated on an annual basis, given that year's precipitation or streamflow and chemical data. The variance of the annual values was used to calculate a standard error and subsequently the 95-percent confidence interval. The net change was calculated as the mathematical difference between input and output. The confidence interval was calculated from a weighted average variance and standard error for the difference (Steele and Torrie 1960).

Precipitation Chemistry

Indian River precipitation is slightly acidic (pH = 6.5) and chemically dilute; however, the large precipitation influx (2300 to 2900 mm per year) results in substantial deposition of elements. Precipitation originates over saltwater and is reflected in the deposition of chloride, calcium, magnesium, sodium, and potassium (Pritchett 1979, Patterson 1976). The total nitrogen (ammonium, nitrate, nitrite, Kjeldahl, and organic) input of 5.5 kg/ha per year must be assumed to originate from soil and ocean surfaces (Wollum and Davey 1975), because anthropogenic sources are not evident (table 1). No explanation is offered as to the ammonium-nitrogen source. The ammonium-nitrogen concentration average in precipitation was high and considered to be a valid measurement. Because samples were collected every 2-4 weeks, interconversion among nitrogen species may occur; however, the total nitrogen content would not change.

Amount of precipitation did not appear to be related to element concentration. Separating element concentrations for separate storms was impossible because of logistics and access to study sites. A study in the North Cascades of Washington State indicated no consistent chemical differences in precipitation samples collected at a range of elevations and subsequently volumes (Dethier 1979). Preliminary investigations did not indicate element concentration enrichment by dry deposition on surface snow layers.

Element inputs to Indian River were calculated by precipitation amounts and volume-weighted concentrations and averaged for the 1979 and 1980 water years. Streamflow outputs were determined for water years 1977-80. Elemental transfers in Indian River are comparable to geochemical studies of other watersheds. (table 2).

Runoff Chemistry

Water chemistry samples from Indian River have been collected since 1976. Volume (discharge)-weighted concentrations and streamflow data were used to calculate annual streamflow losses for water years 1977-80. Water chemistry samples often contained suspended sediment; however, the transport of elements associated with sediment was not measured. Sediment movement occurred during the higher peakflows on the rising limb of the hydrograph and was composed of 5- to 25-percent organic materials. The organic material could act as exchange sites. Therefore, element outputs in streamflow do not indicate total watershed output.

The alkalinity of runoff waters averaged 10.47 mg/1, and the near neutral pH (7.2) was not apparently related to discharge or season. Alkalinity increased from precipitation inputs because of interactions with the biological and pedological components. Changes in pH and alkalinity may be influenced by the presence of organic acids as evidenced by solution color.

Dissolved cation outputs are about 400 kg/ha per year with an anion output of 300 kg/ha per year. Additional ion transport may result from organic acids or association with suspended sediments. The output:input ratio of the cations calcium, magnesium, sodium, and potassium is 4.8—comparable to the 3.3 of Jamieson Creek (Zeman 1975), and 4.8 of the Olympics (Larson 1979), but less than the 12.0 of the H.J. Andrews Experimental Forest in Oregon (Henderson et al. 1978).

Nutrient conservation occurred for total nitrogen (+1.0 kg/ha per year) and ammonium nitrogen (+3.3), but all other element transfers exhibited a net loss. Losses ranged from 0.1 kg/ha per year of total phosphorus to 256 kg/ha per year of calcium. The average net change (element gain or loss) was calculated as the mathematical difference between input and output (table 1).

Table 1—Summary of average precipitation input (1979-80), streamflow output (1977-80), and average net change all with 95-percent confidence intervals

Element	Input	Output	Net change
	Kilograms/hectare per year		
Total N	5.5 ± 3.4	4.5 ± 0.8	+ 1.0 ± 1.2
NH_4N	4.7 ± 2.8	1.4 ± 0.3	+ 3.3 ± 0.5
NO_3N	0.5 ± 0.3	2.2 ± 0.4	− 1.7 ± 0.5
Total P	0.7 ± 0.4	0.8 ± 0.2	− 0.1 ± 0.3
PO_4P	0.5 ± 0.8	0.4 ± 0.6	+ 0.1 ± 0.1
SO_4S	9.6 ± 5.8	22.8 ± 4.2	− 13.2 ± 5.6
C1	20.3 ± 12.2	90.1 ± 16.7	− 69.8 ± 21.8
HCO_3	23.4 ± 14.1	183.5 ± 33.7	−160.1 ± 44.3
Si	1.7 ± 0.9	34.1 ± 6.3	− 32.4 ± 8.2
Ca	18.8 ± 11.3	275.0 ± 50.6	−256.2 ± 66.2
Mg	12.3 ± 7.4	24.0 ± 4.4	− 11.7 ± 5.9
Na	38.4 ± 23.1	39.6 ± 7.3	− 1.2 ± 9.6
K	4.0 ± 2.4	10.3 ± 1.9	− 6.3 ± 2.5

Table 2—Summary of precipitation inputs and streamflow outputs for Indian River, Jamieson Creek (British Columbia), western Olympic Peninsula (Washington State), and Watershed West (New Hampshire)

	Indian River (2-yr input) (4-yr output)		Jamieson Creek[1] (1 yr)		Olympic Peninsula[2] (2-yr average)		Watershed West[3] (1 yr)	
Element	Input	Output	Input	Output	Input	Output	Input	Output
	Kilograms/hectare per year							
Total N	5.5	4.5	—	—	3.8	2.2	—	—
NH_4N	4.7	1.4	0.5	0.4	—	—	2.8	0.4
NO_3N	0.5	2.2	1.1	0.8	0.7	1.3	6.0	6.6
Total P	0.7	0.8	—	—	1.1	1.0	—	—
PO_4P	0.5	0.4	0.1	0.2	1.2	0.8	—	—
SO_4S	9.6	22.8	2.1	3.0	10.8	83.0	17.3	22.9
C1	20.3	90.1	23.1	38.1	—	—	—	—
HCO_3	23.4	183.5	7.6	37.2	90.5	1220.0	0	41.9
Si	1.7	34.1	0.4	48.9	0	102.0	—	—
Ca	18.8	275.0	7.3	41.7	10.5	320.0	3.1	26.4
Mg	12.3	24.0	2.2	8.8	6.0	44.5	0.7	3.8
Na	38.4	39.6	13.2	25.6	82.0	112.5	1.3	13.1
K	4.0	10.3	0.9	2.6	3.8	12.0	2.4	7.0

[1]Zeman, 1975.
[2]Larson, 1979.
[3]Martin, 1979.

Discussion

Chemical composition of streamflow water can come either from tropospheric fallout—including elements originally derived from the ocean, terrestrial sources, or biological fixation. The tropospheric contributions of each element can be expressed as a percentage of streamflow output (table 3). Sulphate sulfur, chloride, bicarbonate, silica, calcium, magnesium, and potassium are largely derived from terrestrial sources.

The conservation of nitrogen in the system may be attributed to utilization of ammonium or nitrate nitrogen by forest flora, actual storage of the nitrogen in the soil, or both. The input of nitrogen as ammonia was greater than the nitrate nitrogen input, a similar observation but of greater magnitude than that in the H. J. Andrews Experimental Forest (Henderson et al. 1978). The majority of streamwater nitrogen output from undisturbed watersheds occurs in organic forms (Fredriksen 1972). Nitrogen budgets are assessed through hydrologic processes and do not reflect transfers through gaseous forms, nitrogen fixation, or denitrification. Denitrification is probably not appreciable in the forest soils, because they are acid, well drained, and aerated. Denitrification and volatilization, however, may be occurring in muskegs, where precipitation collectors were located, and account for the ammonium nitrogen input.

The total loss of phosphorus of 0.1 kg/ha per year results from weathering of the apatite series, which consists of orthophosphate (Hem 1970). Phosphorus concentrations in naturally occurring surface waters are usually small because of its utilization by aquatic vegetation (Hem 1970). Fixation of phosphate in soils containing appreciable amounts of hydrated iron and aluminum oxides—typical of podzolized soils—restricts phosphate movement (Zeman 1975). The

Table 3—Percent contribution of chemistry from tropospheric sources for streamflow water from Indian River, Jamieson Creek (British Columbia), and Western Olympic Peninsula (Washington State)

Constituent	Indian River	Jamieson Creek	Olympics
Total N	122	—	173
NH_4N	336	106	—
NO_3N	23	138	54
Total P	88	—	110
PO_4P	125	55	150
SO_4S	42	74	13
C1	23	61	—
HCO_3	13	20	7
Si	5	1	0
Ca	7	17	3
Mg	51	25	13
Na	97	51	73
K	39	34	32

mechanisms of organic phosphorus retention by soils have not been fully established. Although organic phosphorus is reported to leach from soils, a large proportion of the organic phosphorus appears to be removed as particulate matter rather than as dissolved phosphorus (Fredriksen 1972).

Chloride is present in certain of the minerals of the igneous rocks, such as chlorapatite or as apatite in limestone (Mason and Berry 1968), but these minerals have a limited distribution in Indian River Valley (Loney et al. 1975). Not all of the chloride output is believed to come from weathering of this parent material. During dry periods, forest canopies are effective interceptors of chloride from sea salt in the dry state. Rains in late summer and fall wash out salts accumulated on the foliage (Eriksson 1955).

The net loss of sulfur (−13.2 kg/ha per year) may be the result of weathering of sulphur-bearing minerals within the watershed. Pyrite occurrences are not uncommon (Loney et al. 1975). Decomposition of organic matter is another possible source of vadose sulphur compounds (Zeman 1975). This may be important in organic soil (muskeg) areas. The net outflow of sulfur is attributed to dissolution of sedimentary rocks and from organic material containing sulphur (Rainwater and Thatcher 1960). A hot-water spring, containing sulfur, exists in the community of Tenakee Springs. The extent of this spring or other hot springs in Indian River Valley is not known.

The principal source of magnesium in natural waters is ferromagnesian minerals in igneous rocks and magnesium carbonate in carbonate rocks (Hem 1970). The potassium content in natural waters is usually small. Potassium occurs in rocks in a form not easily brought into solution, although several geochemical processes tend to remove potassium selectively and return it to the solid phase (Hem 1970).

Sodium is very soluble and readily leached from soil, mineral, or bedrock. Once in solution, sodium tends to remain there. Calcium is dissolved from practically all rocks, but is usually found in greater quantities in waters leaching limestone, dolomite, or gypsum deposits (Hem 1970).

The precipitation input of calcium (18.8 kg/ha per year) as well as potassium, sodium, and magnesium largely originates as an aerosol over saltwater (Pritchett 1979). The net calcium loss of 256 kg/ha per year is from dissolution and weathering of a linear outcrop of Kennel Creek limestone. Similarly, the losses of magnesium, sodium, and potassium at 11.7, 1.2, and 6.3 kg/ha per year, respectively, may be dissolution and weathering of limestone, as well as potassium and sodium feldspars and the available hornfels, schists, and amphiboles.

The elemental balances from Indian River are comparable to similar studies in forested watersheds. Indian River had an average annual precipitation of 2700 mm, Jamieson Creek in British Columbia had 4540 mm for the 1970-71 water year (Zeman 1975), and the Olympic Peninsula averaged 4230 mm (Larson 1979). No precipitation or streamflow data were presented for Watershed West (Martin 1979).

Though precipitation was less than in the other studies, element inputs or outputs are comparable to them because of higher concentrations of elements. The large input of total nitrogen to Indian River is not observed in the other cited studies; however, nitrogen conservation still occurs.

During the early stages of succession when production and biomass accumulation are rapid, nutrients essential to plant growth may be retained in the biomass with a reduction in concentration of streamwater. As the forest matures and net production declines, uptake of essential nutrients will be reduced and these nutrients will be leached out of the system in streamwater (Vitousek 1977, Vitousek and Reiners 1975). Nitrogen and phosphorus accumulate while the other essential plant nutrients have a net loss in Indian River. The nutrient budgets of nonessential ions—chloride, bicarbonate, and sodium—should be unaffected by successional stage. The biogeochemistry of cations seems to be strongly controlled by precipitation, soil water movement, chemical weathering of bedrock materials, and movement of suspended sediment, rather than forest succession.

Geochemical influences on streamwater chemistry are evident in this forested watershed. Water quality is influenced by the mineral composition and solubility of underlying rocks. Water percolating through soil and substrata en route to the stream may be enriched with dissolved solids. A correlation between the mineral composition of water and that of the geologic formation with which the water has been in contact seems reasonable. The major constituents of sodium, calcium, magnesium, bicarbonate, sulphate, chloride, and silica may be readily influenced by bedrock weathering, depending on the bedrock with secondary constituents of iron, potassium, carbonate, nitrate, fluoride, and boron influenced less (Davis and DeWiest 1966). Note that the weathered elements coming from geologic formations can be overshadowed by other effects. Differences in climate or other influences on the weathering process can produce very different types of water from essentially similar rock sources (Hem 1970). A satisfactory system of classifying water based entirely on composition of source rocks is unlikely.

Conclusions

Indian River receives about 140 kg/ha per year of dissolved solids in 2700 mm of precipitation. Average annual losses in streamflow are 700 kg/ha per year of dissolved solids and do not include elemental losses associated with sediment transport or gaseous transfers. Total nitrogen accumulated in the watershed at a rate of 1.0 kg/ha per year. Other monitored elements had greater streamflow losses than precipitation inputs. Precipitation (tropospheric) inputs accounted for 5-336 percent of the elemental losses in streamflow.

Individual storm volumes and element concentrations were not investigated because of limited access to the study area during the rainy fall months. The relation of streamflow to element concentrations was not apparent; however, volume-weighted concentrations were used to portray elemental gains and losses more accurately.

The terrestrial sources of elements are from soil (pedogenic) and bedrock weathering. The presence of a linear outcrop of Kennel Creek limestone and associated minerals can account for the bulk of element addition to the streamwater. Calcium as well as sodium, potassium, and magnesium losses were largely from limestone. Potassium and sodium were also derived from available hornfels, schists, and amphiboles. Phosphorus and sulfur were derived largely from apatite and pyrite, respectively. No effort was made to separate elements weathered from the soil and those from bedrock.

The elemental losses from Indian River are comparable to similar studies in mountainous and forested watersheds. The nitrogen budget distinguishes Indian River from other watersheds studied, however.

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Water chemistry samples have been taken from streamflow since 1976 and precipitation since 1978 in Indian River, an undisturbed watershed on Chichagof Island in Southeast Alaska. Volume-weighted concentrations of total nitrogen, ammonium nitrogen, nitrate nitrogen, total phosphorus, orthophosphate, sulfate sulfur, chloride, bicarbonate, silica, calcium, magnesium, sodium, and potassium were used with precipitation and streamflow volumes to calculate annual input and output of elements. Total nitrogen accumulated at 1.0 kg/ha per year and ammonium-nitrogen at 3.3 kg/ha per year; other monitored elements showed a net loss or export from 0.1 kg/ha per year of total phosphorus to 256 kg/ha per year of calcium. Precipitation and weathering of soil and bedrock material account for these elemental losses in streamflow. The geochemistry of Indian River is compared to other studies done in mountainous forested watersheds.

Keywords: Water analysis, nutrient budget, precipitation, streamflow, southeast Alaska.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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